Figure 12 – Highway Overpass, Test Results Summary

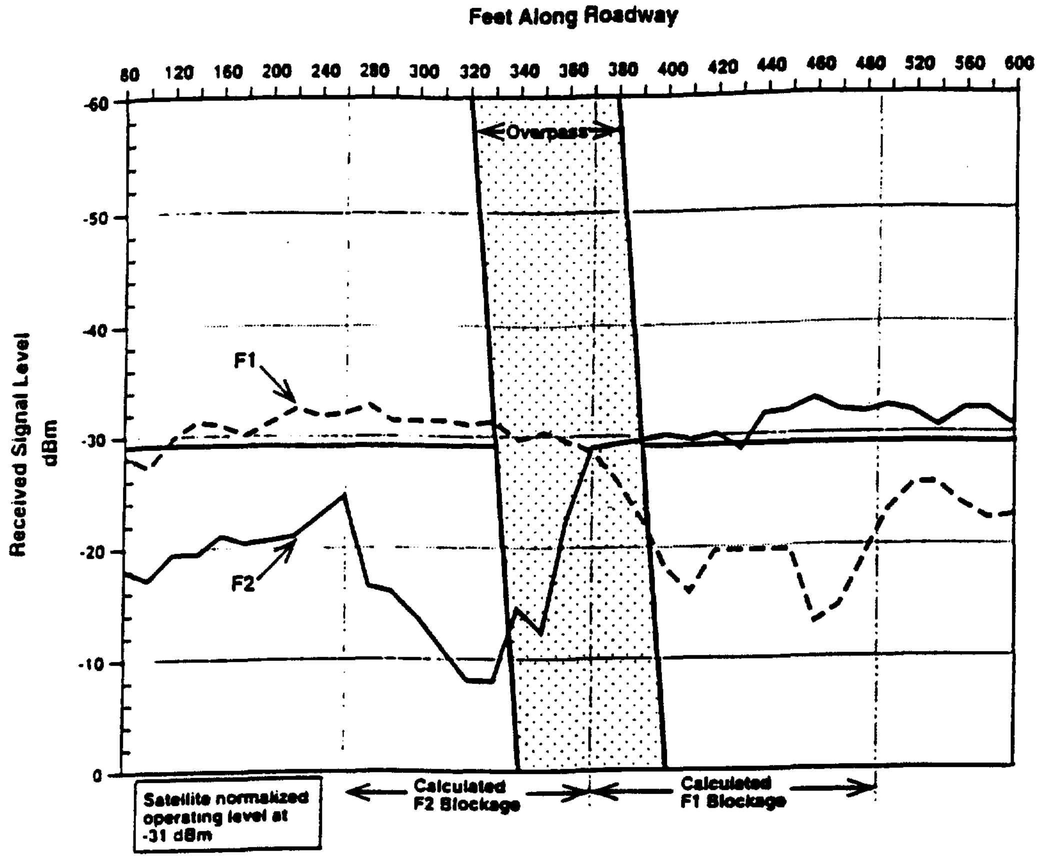
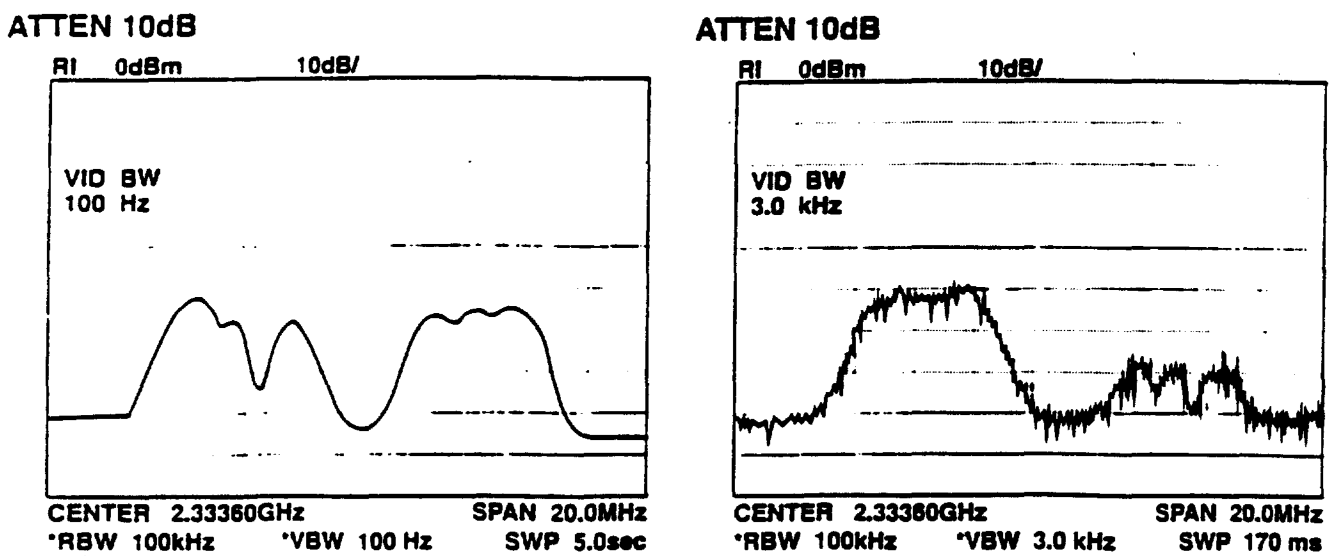


Figure 13 – Test Range Spectrum Plots



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[redacted]

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William Caton, Acting Secretary
Federal Communications Commission
1919 M Street, NW Room 222
Washington,, D.C. 20554

Re: PP-24, Experimental License KO2XES

Dear Mr. Caton:

Pursuant to Section 5.204 of the Commission's Rules, 47 C.F.R. § 5.204 (1994), attached is the most recent experimental report showing the progress of CD Radio Inc. testing and experimentation in connection with its experimental license and pending application for pioneer's preference. The report covers recent use of an S-Band satellite (NASA TDRS) to characterize the satellite-to-mobile path in the digital audio radio service (DARS). In particular, the experimentation was designed to determine the extent to which blockage, shadowing and multipath conditions created polarization reversal in the received signal.

If there are any questions about the foregoing, please contact the undersigned.

Sincerely,

Carl R. Frank
Counsel for Satellite CD Radio, Inc.

Attachment
cc: Rodney Small

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List A B C D E

NASA and CD Radio's TDRSS Industrial Test Program

Robert D. Briskman - CD Radio Inc.
1001 22nd Street, N W , Wash, DC 20037 USA
Phone: 202-296-6840 Fax: 202-296-6265

James E. Hollansworth - NASA Lewis Research Center
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ABSTRACT

The National Aeronautics and Space Administration (NASA) has embarked on a joint test program with CD Radio Inc. The program will demonstrate spatial diversity techniques in support of industrial development of a new satellite direct-broadcast national radio service called Satellite Radio. Satellite Radio will operate in the FCC approved frequency band 2310-2360 MHz which is close to NASA's Tracking and Data Relay System (TDRSS) satellites' high power transmit frequency near 2110 MHz. The cooperative test program in which NASA provides use of a TDRSS satellite and CD Radio provides the measurement equipped vehicle is described as well as its current status. Some initial measurement data are presented.

INTRODUCTION

Direct broadcast of radio programming from satellites to listeners in mobile vehicles, primarily automobiles and trucks, and in homes will be available before the end of the century. The service is called Satellite Radio and will operate in the Federal Communications Commission's approved frequency band 2310-2360 MHz. The service will provide listeners with diversity of radio programming, particularly in rural areas; niche programming, including foreign language and ethnic channels; and educational and cultural opportunities on a nationwide basis. Technical development, manufacturing and industrial benefits are also foreseen. Providing high quality Satellite Radio service to mobile vehicles requires that service outages, which are primarily caused by multipath and physical blockage be made extremely infrequent. CD Radio intends to accomplish this by use of satellite spatial diversity in conjunction with other outage mitigation methods. Additional measured data on satellite spatial diversity at S-band frequencies would be useful, and a cooperative program with the National Aeronautics and Space Administration (NASA) was derived using the government's Tracking and Data Relay Satellite System, whose satellites can transmit with reasonable power at S-band (approximately 2110 MHz). The industrial test program is described in the following material.

SYSTEM/EXPERIMENT DESCRIPTION

The long range program is the accumulation of data on satellite spatial diversity performance for mobile reception in automobiles over a wide range of environments and conditions. This includes the various terrains throughout the country, operation in suburban/urban areas, effects of elevation angle to the satellites, and of trees, etc. The data will take the form of service outage occurrences and the length of such occurrences as a function of the previously mentioned conditions. The duration of the experiment is expected to be lengthy for several reasons, one of which is that measurements can only be performed when the TDRSS satellites are not being used for government purposes or for other experiments and as a function of the satellites' orbital locations.

The first phase of the experiment program has been initiated and will be described in the following material. The objective of the first phase was to characterize precisely the TDRS-to-automobile path in a mobile environment. The goal is to obtain field strength and polarization characteristics of the path over the eastern half of the contiguous United States. This can be done from the TDRS-East at elevation angles of interest (i.e., 20°-35°).

The measurement system utilizes a NASA

uplink which generates a Ka-band carrier to the TDRSS satellite sufficient to saturate the satellite's S-band transmitter. NASA also positions the satellite antenna beam to the portion of the eastern half of the U.S. where measurements are to be made that day. The S-band carrier is transmitted from the satellite using right hand circular polarization (RHCP). The measurement vehicle was developed, instrumented and operated by CD Radio. It is a passenger automobile with an instrument pod mounted on the roof containing a RHCP receiving antenna, a LHCP receiving antenna, and a Global Positioning System (GPS) antenna with the preamplifiers, detectors and a data acquisition system inside the car. Figure 1 is a simplified system depiction and Figure 2 shows a typical TDRS satellite downlink antenna coverage. Essentially, the amplitude of the received right and left hand polarized satellite transmissions are measured as a function of the automobiles physical location and time.

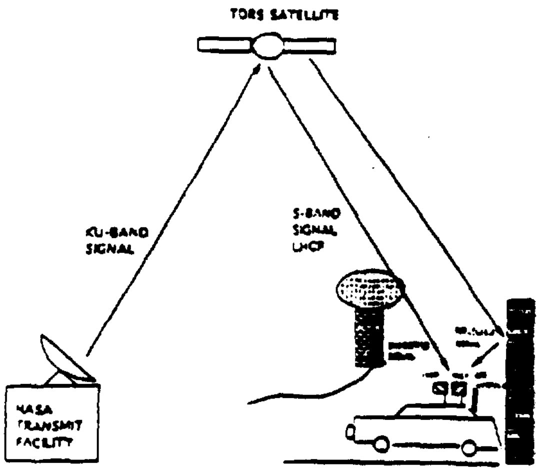

Figure 1 - System Configuration

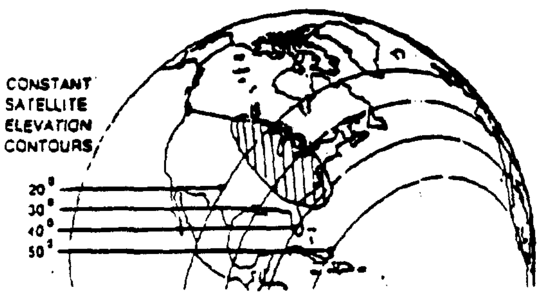

Figure 2 - S-Band Beam from TDRS at 45 Degress West

The link budget is based on a satellite beam center EIRP of 46.4 dBW (i.e., a flux density of -116 dBW/m²/4kHz). A nominal path loss of -190.5 dB, a receiving beam center car antenna gain of 3.5 dBi and losses of 1.2 dB result in a received power of -141.8 dBW. The receiver noise power in its 1 kHz detection bandwidth is -176.3 dBW. Assuming good measurement precision at a C/N of 8 dB and averaging over 200 samples, fading of 26 dB can be accurately measured. The TDRS antenna's maximum axial ratio over the 3 dB beamwidth is 1.5 dB and the automobile antennas are similarly specified. An axial ratio of 1.5 dB reflects a cross-polarization rejection of 21 dB. However, since most measurements were made closer to beam center where axial ratios are better, the total polarization isolation is estimated as 25 dB ± 5 dB.

The following sections describe in more detail the space segment, the measurement vehicle and early measurement results.

SPACE SEGMENT

The NASA/CD Radio TDRSS Industrial Test program is based upon the Space Act of 1958 (42 U.S.C. 2451 et seq.) sections 203(c)(5)and 203(c)(6) and as implemented by NASA Management Instruction (NMI)1050.9A. The purpose of the Space Act Agreement is to conduct joint experimental programs between NASA and U.S. Industry for public benefit, U.S. manufacturing and obtaining technical data and development. There are two general types of Space Act Agreements called for (1) Reimbursable and (2) Non- Reimbursable.

NASA's Space Act Agreement with CD Radio is Non-Reimbursable and calls for the obtaining of technical data regarding satellite reception of digital audio radio at S-band on mobile platforms. The experimental program includes the testing of polarization isolation, diversity reception techniques and advanced automobile antennas at S-band.

The NASA satellite constellation that is being used for the CD Radio Industrial Test is the Tracking and Data Relay Satellite System (TDRSS) as shown in Fig.3. This system operates at both S-band (2025-2300 MHz) and at Ku-band (13.7-15.3 GHz). Single-access services in the S-band and Ku-band ranges use the umbrella-shaped, steerable 4.9-meter parabolic dish antennas to communicate with one user at a time. Operating in the S-band and Ku-band frequencies, the TDRSS can handle up to 300 million bits of information each second from a user, the equivalent of the material in a 20 volume encyclopedia.

Tracking and Data Relay Satellites communications is controlled from two ground terminals located at White Sands, New Mexico. This site was chosen for its low geographic latitude within the United States, affording a clear view of the satellites, and because service interference caused by weather was minimal. The terminals are responsible for maintaining such functions as transmitting commands to the spacecraft, receiving the user data returned through each TDRSS, and keeping track of system status.

Under normal operations all uplink and downlink communications between a TDRSS satellite and the Earth (White Sands, NM) pass through the satellite's 2-meter parabolic dish antenna near the hexagonal satellite body. The NASA/CD Radio Test Program utilizes the same White Sands Uplink but uses the 4.9 meter parabolic dish antenna to transmit digital audio signals to the test vehicle on the ground see Fig 1.

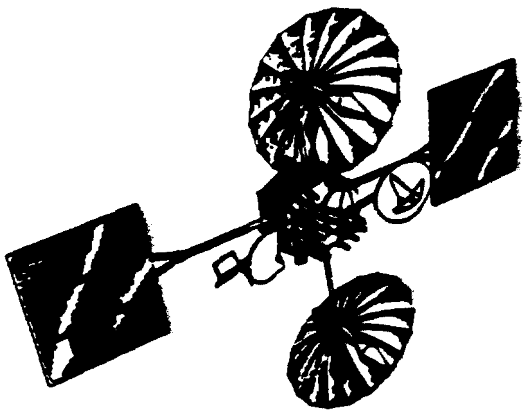

Figure 3 - Tracking and Data Relay Satellite System (TDRSS)

EARTH SEGMENT

The automobile used for the initial measurement phase is shown in Fig. 4 and its equipment block diagram in Fig.5. The LHCP and RHCP antennas are quadrifilar helices. The instrument pod contains microwave S-band absorber material to prevent reflection from the automobile rooftop from affecting the transmission path characterization. The data acquisition computer records the data in blocks, each block having a time stamp (6 bytes), vehicle location, speed and compass heading from the GPS (17 bytes) and the two signal amplitudes (4 bytes). An additional field is to be added allowing vehicle operator insertion of terrain/environment codes. By use of the vehicle tire rotation detector, it is possible to measure data only when the vehicle is in motion. Various equipment calibration and self-test features have been incorporated particularly to keep the receiving system gain, noise temperature and center frequency within required tolerance.

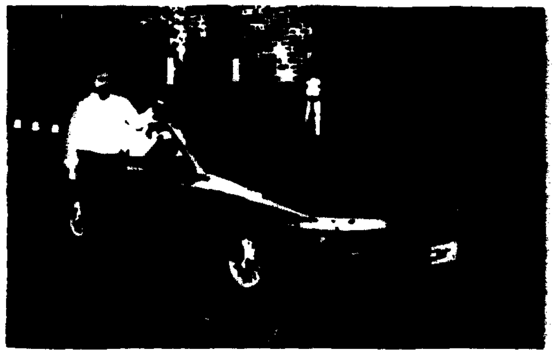

Figure 4 - Measurement Automobile

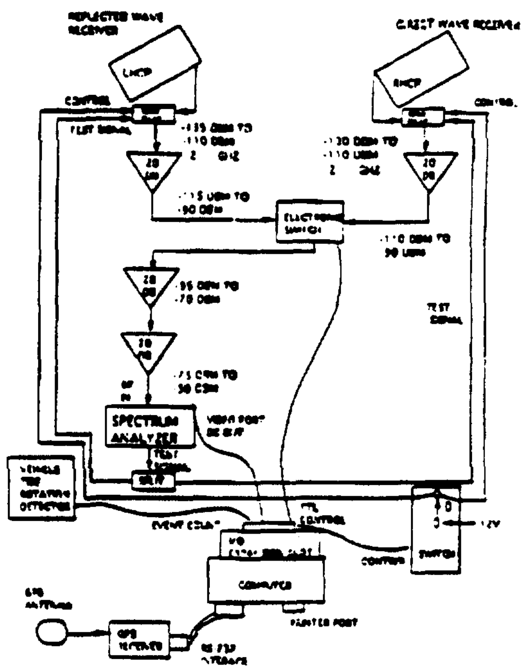

Figure 5 - Test Receiver

EARLY MEASUREMENTS

Several measurement sessions were conducted late last year. The initial one was static for equipment performance and calibration. This was followed by short mobile measurements both to characterize equipment performance in the automobile and to make routine the TDRS scheduling by the NASA Goddard Space Flight Center (GSFC). These tests detected leakage paths in the automobile measuring equipment which were rectified by additional shielding and changes in cable runs and minor software defects. The scheduling by GSFC was handled in an extremely efficient and professional manner. As earlier mentioned, besides finding convenient holes in the busy TDRS schedule, GSFC provides the up-link satellite signal and frequency clearance of the high flux density TDRS down link signal so no interference is caused to other government users of this radio frequency.

Two long duration measurement runs were made on October 30 and 31, 1994 each of several hours. Many hundreds of kilometers were covered including areas of downtown Washington, DC, suburban Virginia and rural Virginia. Data points were measured every 1.5 meters of vehicle movement. A plot of the measured data is shown in Fig. 6 for a rural area with no blockage over a 14 minute period. Fig. 7 is similar for an urban area with blockage and shadowing. The direct signal at the input of the measuring device averaged -70 dBW $\pm$ 0.5 dB and the cross polarized signal averaged -95 dBW $\pm$ 5 dB. The cross polarized received signal consists of the components caused by the lack of perfect polarization circularity (i.e., axial ratio) of the TDRS and automobile antennas, specular reflection where the polarization sense becomes reversed and residual noise from diffuse scattering and the noise floor of the automobile receiver.

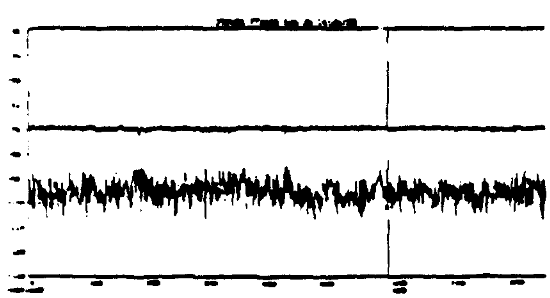

Figure 6 - Measurement Data (Rural)

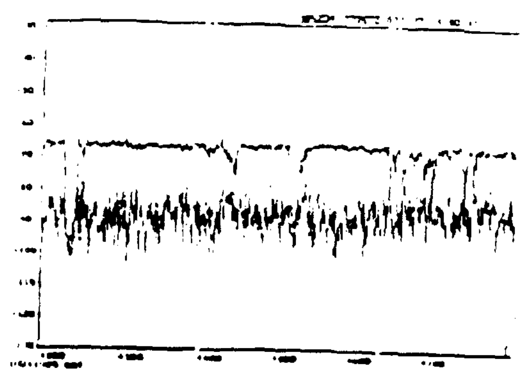

Figure 7 - Measurement Data (Urban)

Preliminary partial analysis of the data indicates relatively few occasions that a significant cross polarization component occurs under non-blockage/shadowing conditions of the direct signal. Significant is meant herein as where the cross polarized component is -12 dB or more with respect to the direct signal. This implies that few non-blocking specular reflections with polarization reversal occur for this satellite elevation angle and ground environment. Conversely, most of the time when the direct signal is blocked or heavily shadowed (attenuated 15 dB or more), the cross polarization component is significant. This implies that specular reflections with polarization reversal occur in blockage or heavily shadowed conditions. This is supported by the fact that the significant cross polarization components are generally of short duration.

SUMMARY

At the conclusion of testing, CD Radio will reduce the data obtained and issue a formal report summarizing the results of the testing. Copies of this report will be made available to NASA and the Federal Communications Commission. This type of cooperative government industry test program has been initiated by NASA and CD Radio Inc. to derive useful data on satellite spatial diversity in connection with the development of a new broadcasting service in the United States which will benefit the public, technology development and manufacturing.

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The United States of America

The Commissioner of Patents and Trademarks

Has received an application for a patent for a new and useful invention. The title and description of the invention are enclosed. The requirements of law have been complied with, and it has been determined that a patent on the invention shall be granted under the law.

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OFFICE OF SECRETARY

Therefore, this

United States Patent

Grants to the person or persons having title to this patent the right to exclude others from making, using or selling the invention throughout the United States of America for the term of seventeen years from the date of this patent, subject to the payment of maintenance fees as provided by law.

Bruce Lehman

Commissioner of Patents and Trademarks

Sandra D. Morton

Attest

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NOTICE

If the application for this patent was filed on or after December 12, 1980, maintenance fees are due three years and six months, seven years and six months, and eleven years and six months after the date of this grant, or within a grace period of six months thereafter upon payment of a surcharge as provided by law. The amount, number, and timing of the maintenance fees required may be changed by law or regulation. Unless payment of the applicable maintenance fee is received in the Patent and Trademark Office on or before the date the fee is due or within a grace period of six months thereafter, the patent will expire as of the end of such grace period.

US005319673A

United States Patent [19]
Briskman

[11] **Patent Number: 5,319,673**
[45] **Date of Patent: Jun. 7, 1994**

[54] **RADIO FREQUENCY BROADCASTING SYSTEMS AND METHODS USING TWO LOW-COST GEOSYNCHRONOUS SATELLITES**

[75] Inventor: **Robert D. Briskman**, Bethesda, Md.

[73] Assignee: **CD Radio Inc.**, Washington, D.C.

[21] Appl. No.: **48,663**

[22] Filed: **Apr. 16, 1993**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 866,910, Apr. 10, 1992, Pat. No. 5,278,863.

[51] **Int. Cl.**[5] H04L 27/30; H04B 7/00
[52] **U.S. Cl.** 375/1; 455/13.1
[58] **Field of Search** 375/1; 342/352, 357, 342/359; 455/12.1, 13.1; 370/75, 109, 50

[56] **References Cited**

U.S. PATENT DOCUMENTS

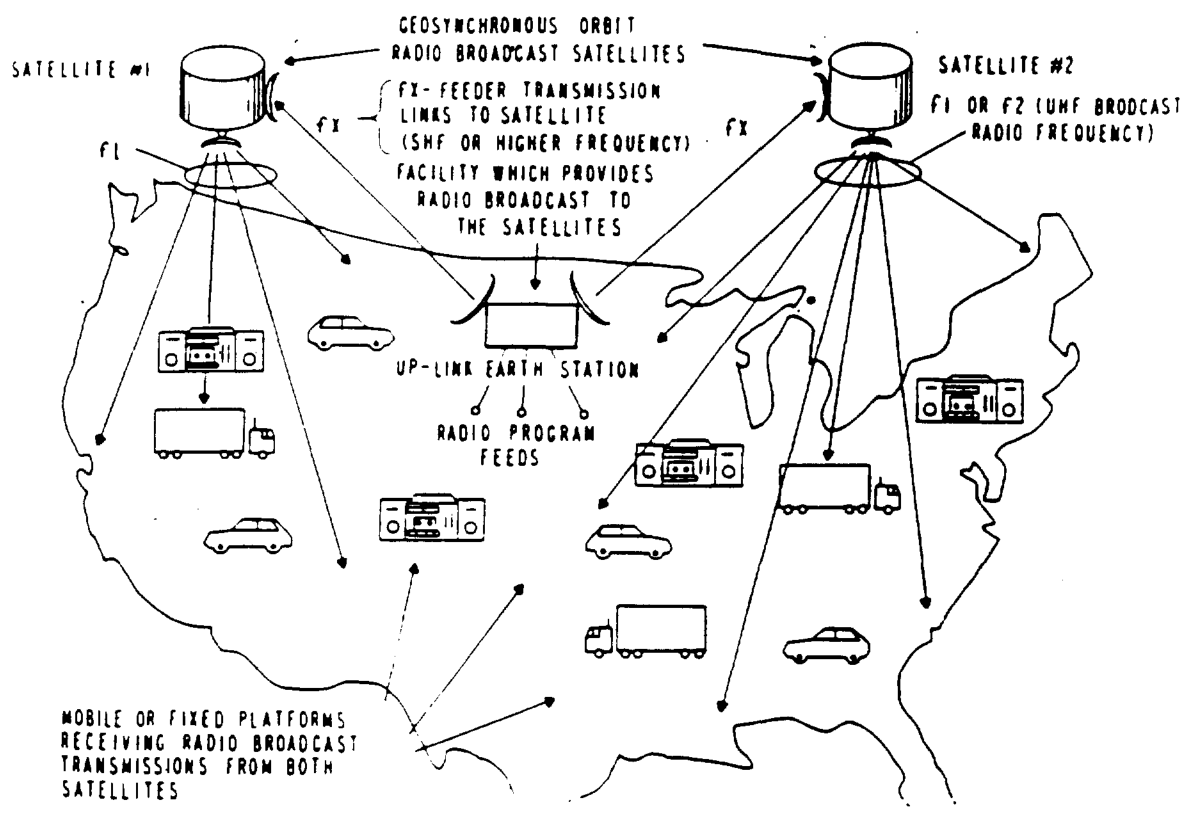
3,836,969	2/1974	Bond et al.	455/13.1
4,630,058	12/1986	Brown	342/352
4,660,196	4/1987	Gray et al.	370/109
4,720,873	1/1988	Goodman et al.	455/12.1
4,801,940	1/1989	Ma et al.	342/359
4,823,341	4/1989	Rosen	455/12.1
4,831,619	5/1989	Rosen	455/12.1
4,879,711	11/1989	Rosen	370/75
4,901,307	2/1990	Gilhousen et al.	375/1
4,943,808	2/1990	Dulck et al.	455/13.1
5,017,926	5/1991	Ames et al.	342/357
5,126,748	6/1992	Ames et al.	342/357
5,153,598	10/1992	Alves, Jr.	375/1
5,175,557	12/1992	King et al.	375/1
5,239,670	8/1993	Schwendeman et al.	455/13.1
5,278,863	1/1994	Briskman	375/1
5,283,780	2/1994	Schuchman et al.	370/50

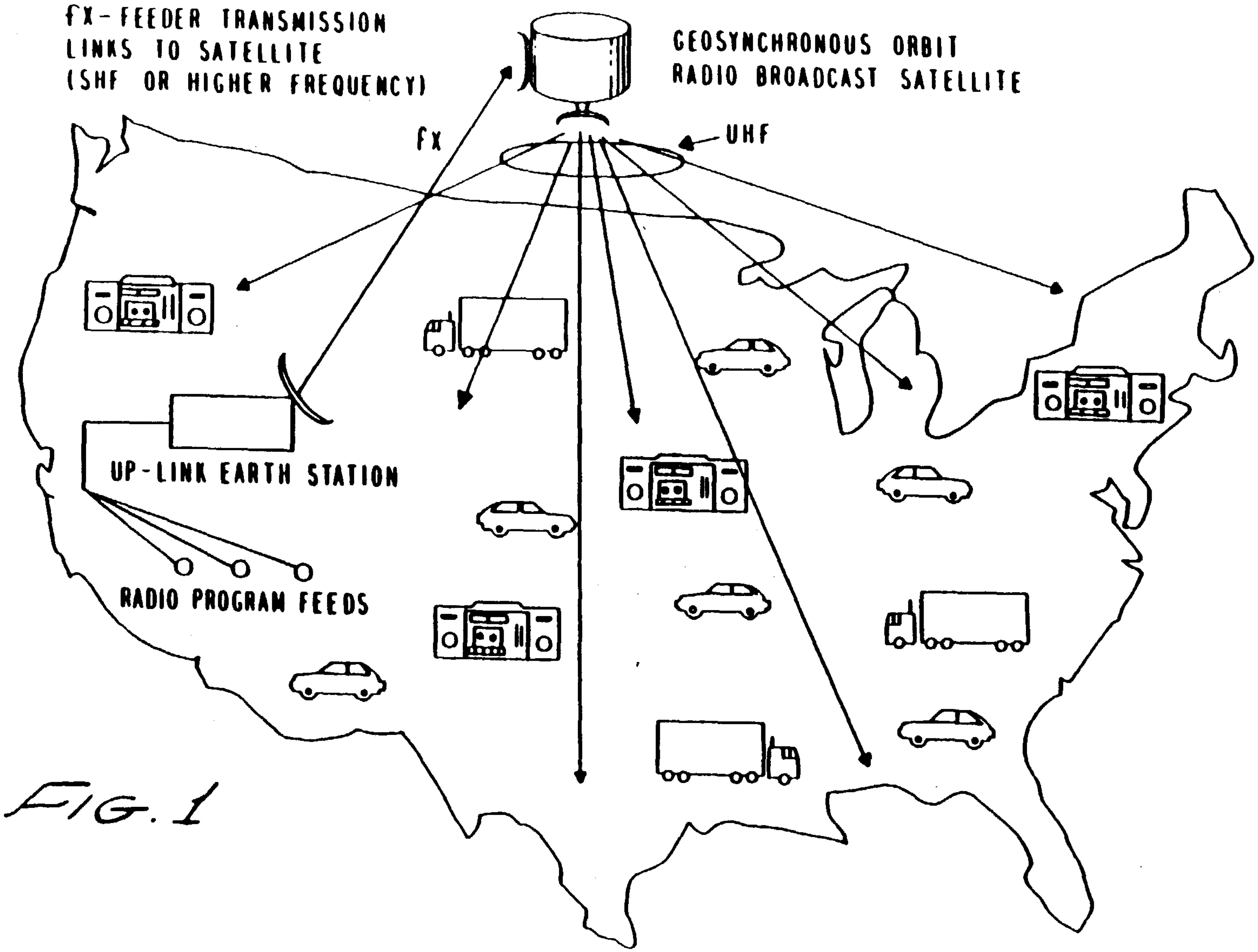
Primary Examiner—Salvatore Cangialosi

[57] **ABSTRACT**

High quality audio broadcasts at radio frequencies to mobile receivers at or near the earth's surface are provided by substantially simultaneous transmission of the same signal from two geosynchronous, spatially-separated satellites on the geosynchronous orbit which virtually eliminates multipath fading and foliage attenuation and thereby permits the use of a low-cost space segment.

28 Claims, 8 Drawing Sheets




FX-FEEDER TRANSMISSION
LINKS TO SATELLITE
(SHF OR HIGHER FREQUENCY)
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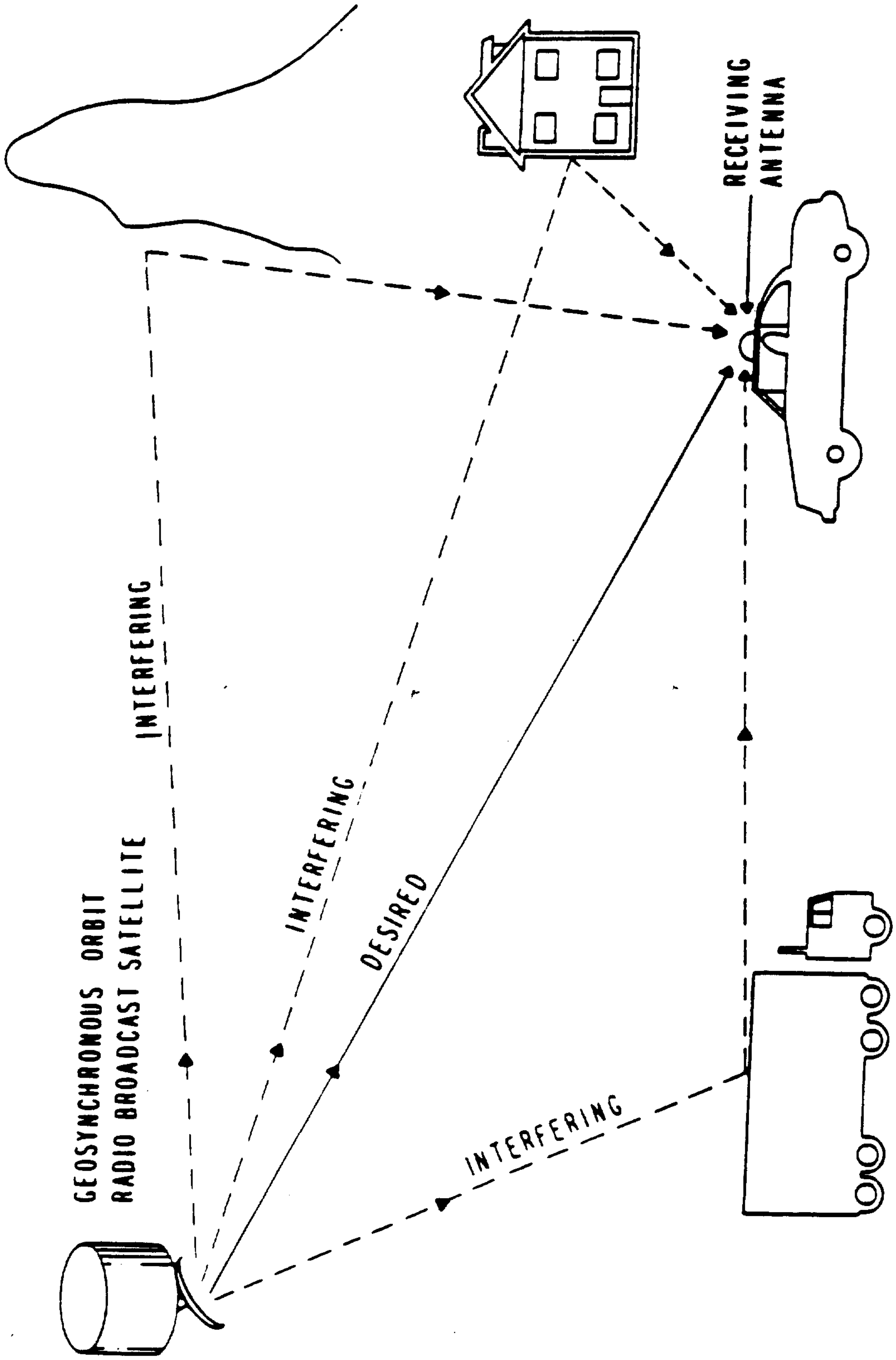
RADIO BROADCAST SATELLITE
FX
UHF
UP-LINK EARTH STATION
RADIO PROGRAM FEEDS

FIG. 1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RADIO BROADCAST SATELLITE
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FIG. 2

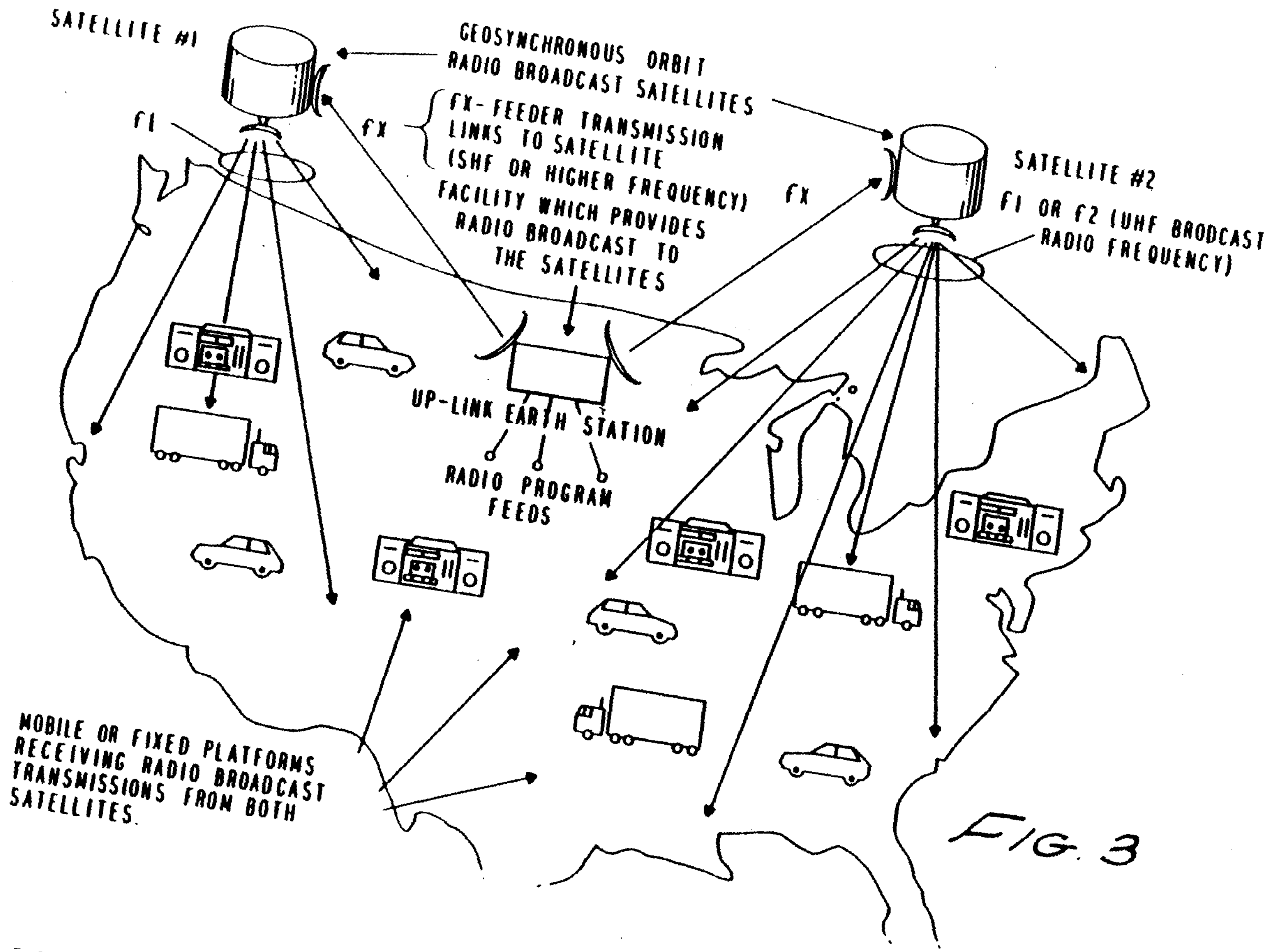
SATELLITE #1
GEOSYNCHRONOUS ORBIT
RADIO BROADCAST SATELLITES
F1
FX
FX- FEEDER TRANSMISSION
LINKS TO SATELLITE
(SHF OR HIGHER FREQUENCY)
FX
SATELLITE #2
F1 OR F2 (UHF BRODCAST
RADIO FREQUENCY)
FACILITY WHICH PROVIDES
RADIO BROADCAST TO
THE SATELLITES
UP-LINK EARTH STATION
RADIO PROGRAM
FEEDS
MOBILE OR FIXED PLATFORMS
RECEIVING RADIO BROADCAST
TRANSMISSIONS FROM BOTH
SATELLITES.

FIG. 3

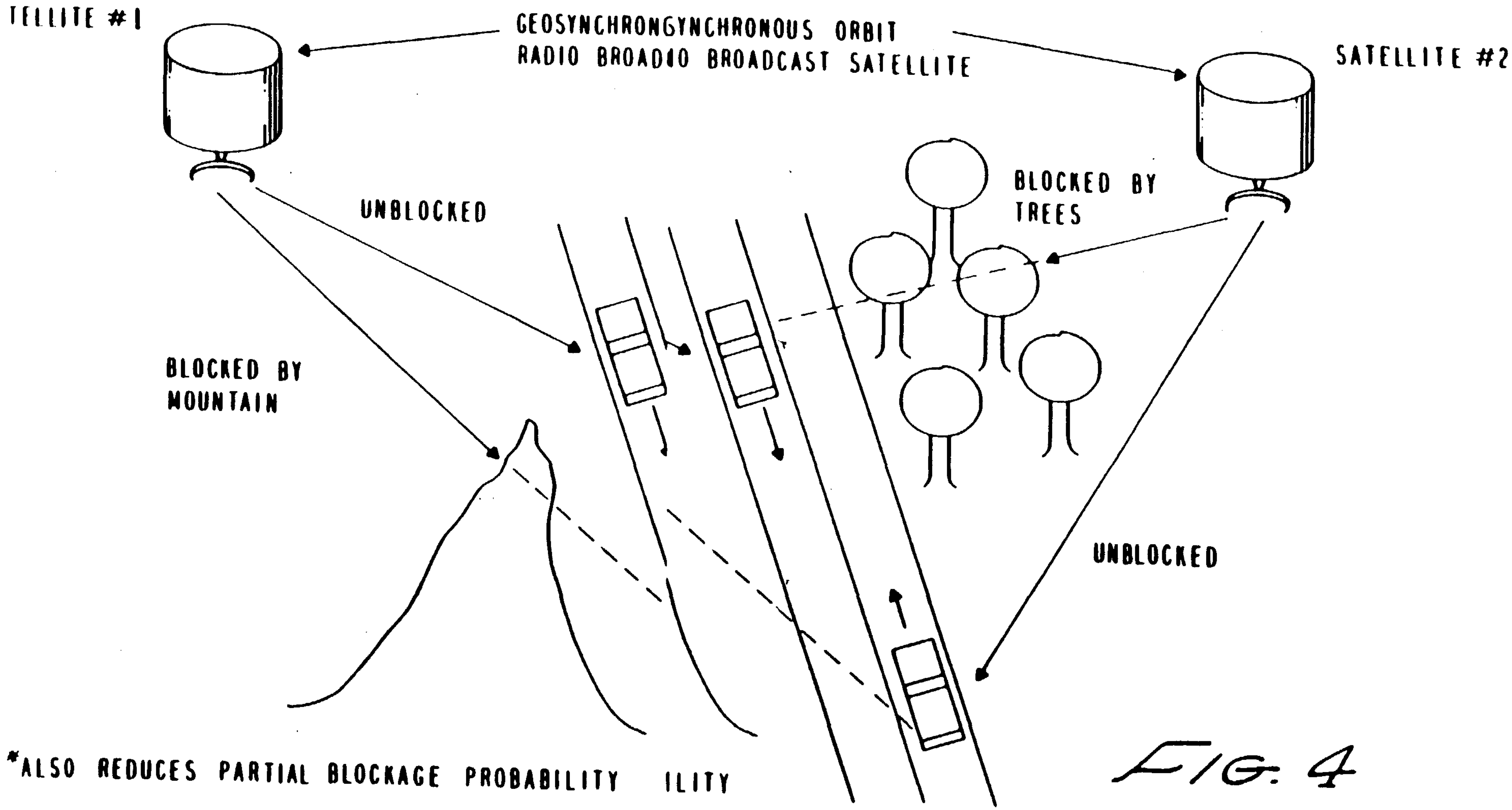
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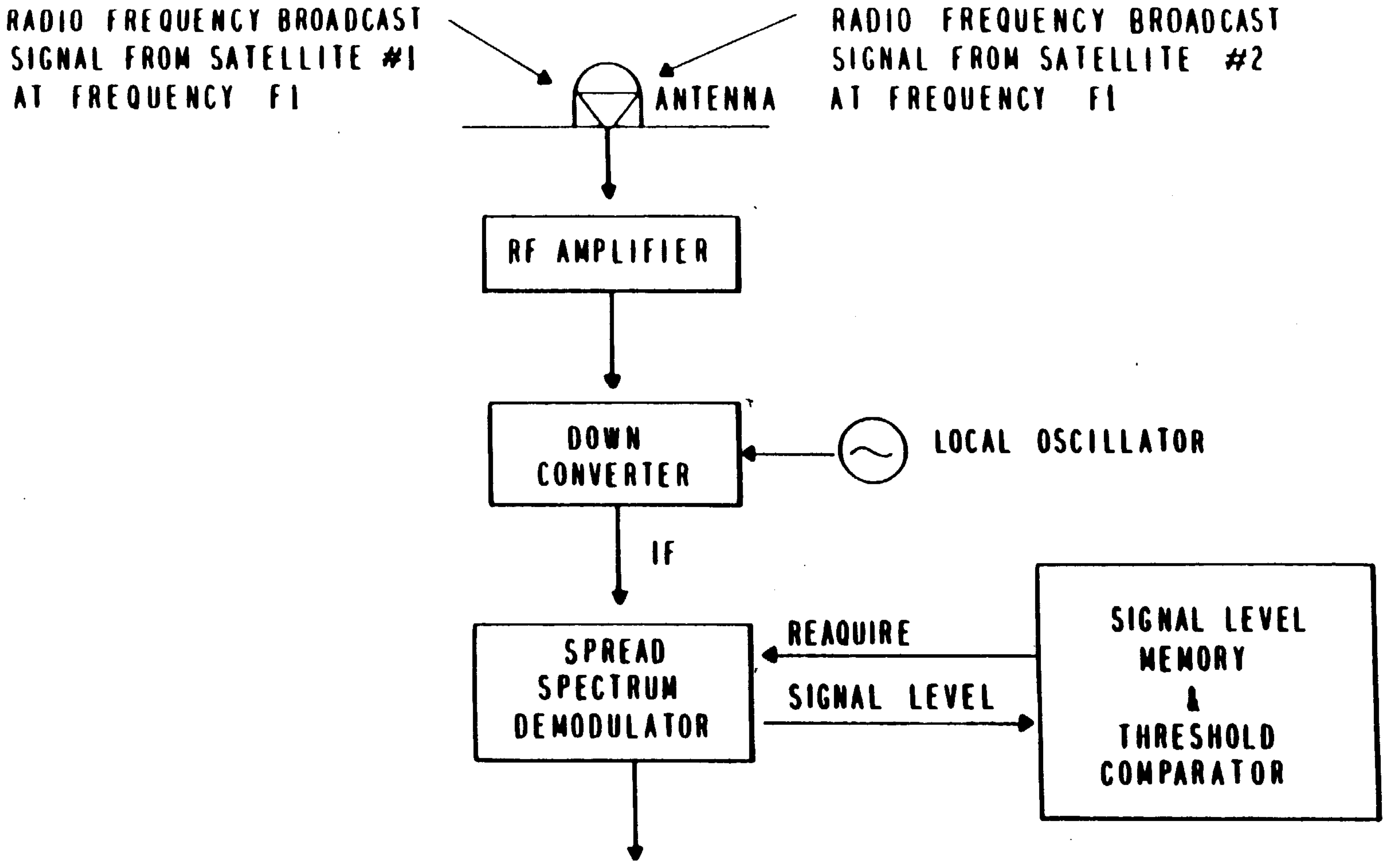
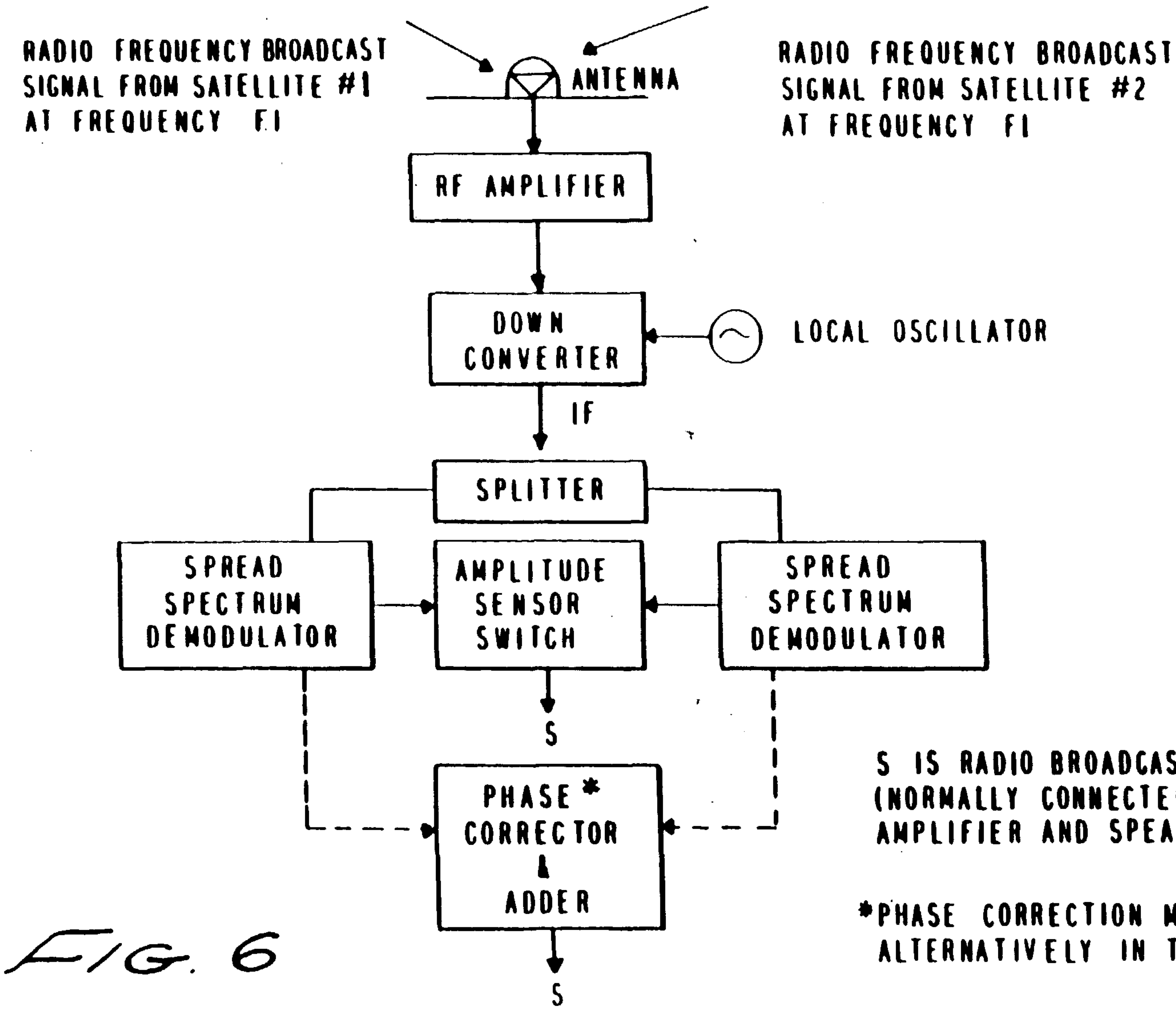
FIG. 4



S IS RADIO BROADCAST AUDIO SIGNAL (NORMALLY CONNECTED TO AUDIO AMPLIFIER AND SPEAKERS)

FIG. 5



S IS RADIO BROADCAST AUDIO SIGNAL (NORMALLY CONNECTED TO AUDIO AMPLIFIER AND SPEAKERS)

*PHASE CORRECTION MAY BE DONE ALTERNATIVELY IN THE DEMODULATORS

FIG. 6

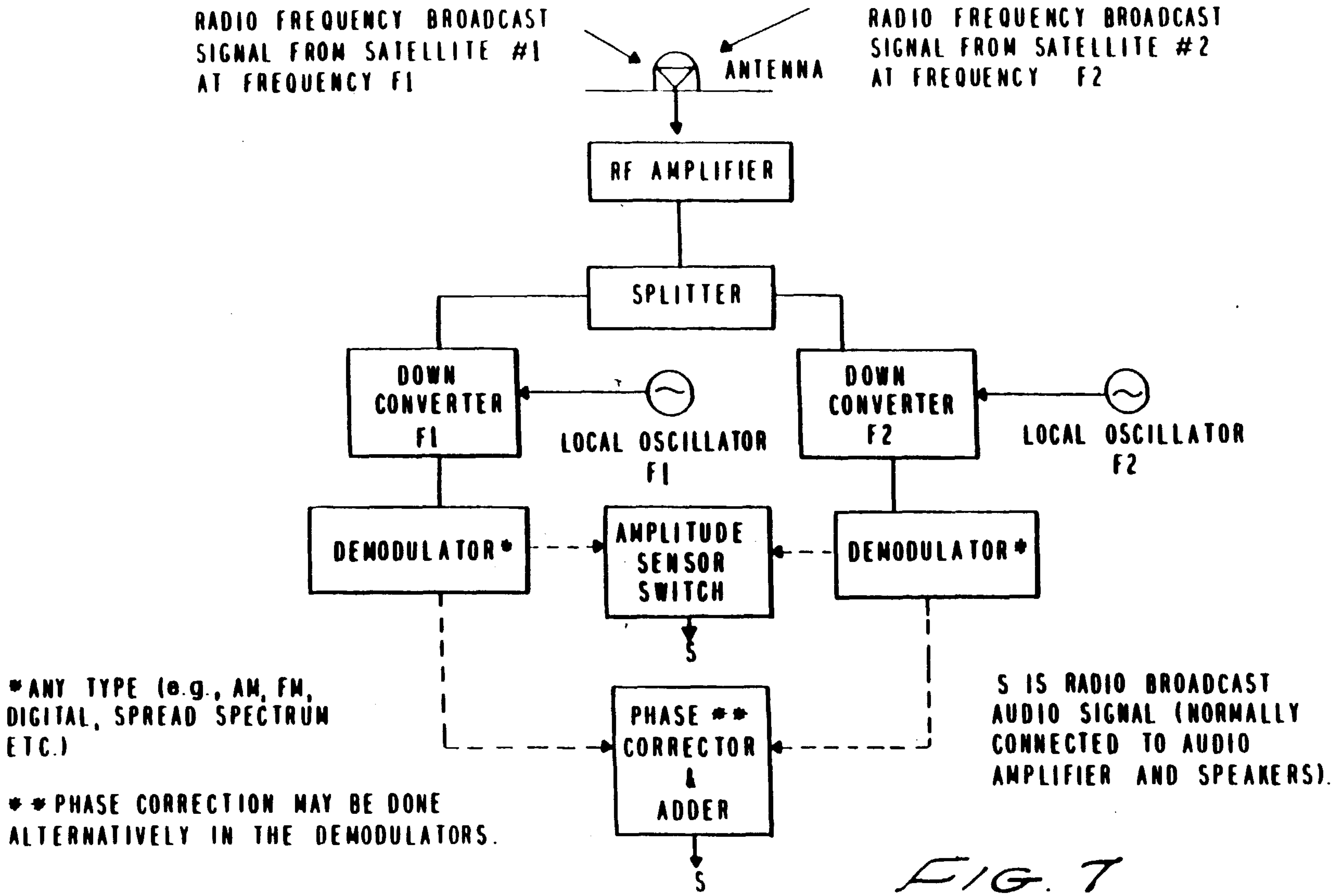

RADIO FREQUENCY BROADCAST SIGNAL FROM SATELLITE #1 AT FREQUENCY F1
RADIO FREQUENCY BROADCAST SIGNAL FROM SATELLITE #2 AT FREQUENCY F2
ANTENNA
RF AMPLIFIER
SPLITTER
DOWN CONVERTER F1
DOWN CONVERTER F2
LOCAL OSCILLATOR F1
LOCAL OSCILLATOR F2
DEMODULATOR*
AMPLITUDE SENSOR SWITCH
DEMODULATOR*
S
PHASE ** CORRECTOR & ADDER
S
*ANY TYPE (e.g., AM, FM, DIGITAL, SPREAD SPECTRUM ETC.)
**PHASE CORRECTION MAY BE DONE ALTERNATIVELY IN THE DEMODULATORS.
S IS RADIO BROADCAST AUDIO SIGNAL (NORMALLY CONNECTED TO AUDIO AMPLIFIER AND SPEAKERS).

FIG. 7

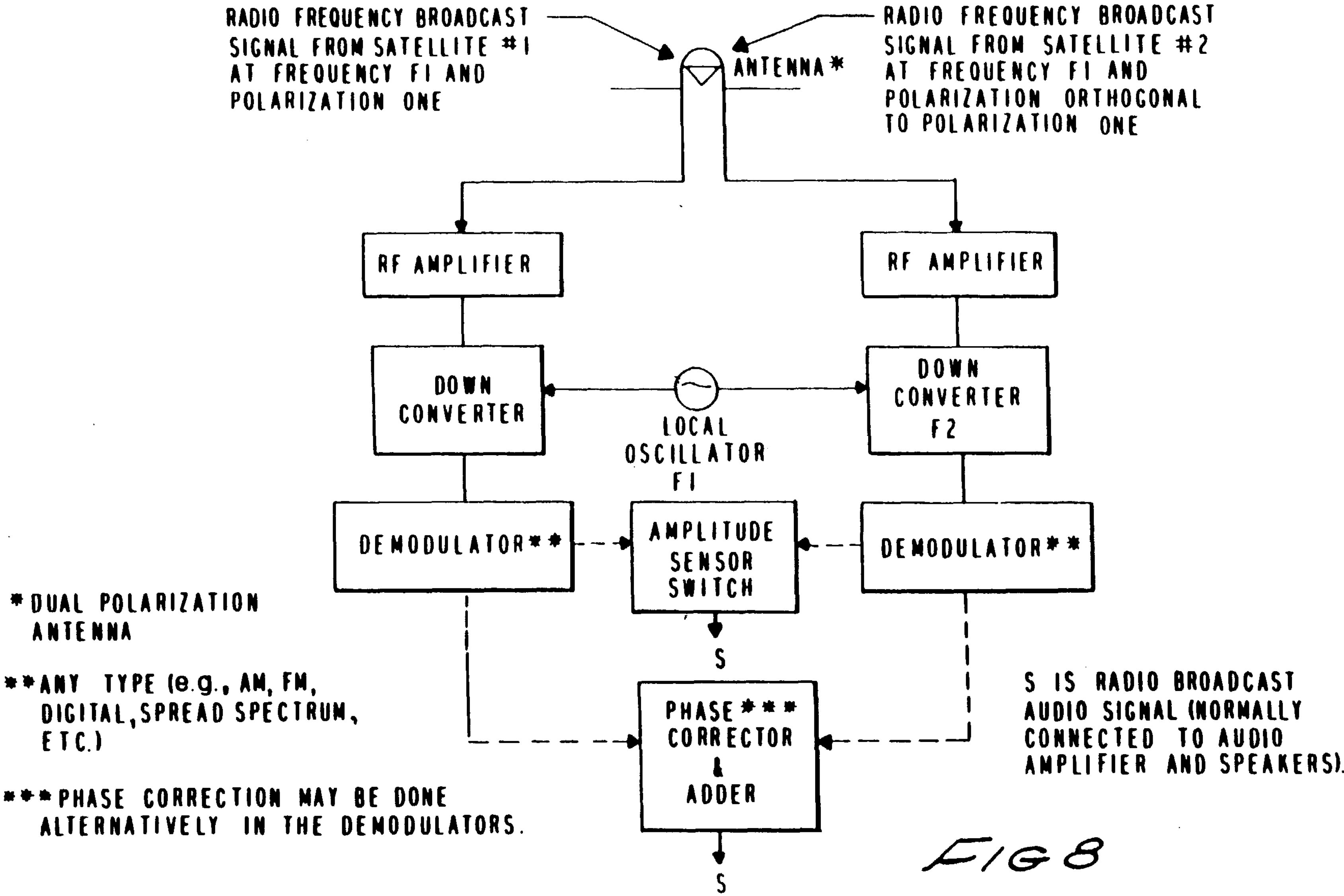

RADIO FREQUENCY BROADCAST SIGNAL FROM SATELLITE #1 AT FREQUENCY F1 AND POLARIZATION ONE
ANTENNA*
RADIO FREQUENCY BROADCAST SIGNAL FROM SATELLITE #2 AT FREQUENCY F1 AND POLARIZATION ORTHOGONAL TO POLARIZATION ONE
RF AMPLIFIER
RF AMPLIFIER
DOWN CONVERTER
LOCAL OSCILLATOR F1
DOWN CONVERTER F2
DEMODULATOR**
AMPLITUDE SENSOR SWITCH
DEMODULATOR**
S
PHASE*** CORRECTOR & ADDER
S
*DUAL POLARIZATION ANTENNA
**ANY TYPE (e.g., AM, FM, DIGITAL, SPREAD SPECTRUM, ETC.)
***PHASE CORRECTION MAY BE DONE ALTERNATIVELY IN THE DEMODULATORS.
S IS RADIO BROADCAST AUDIO SIGNAL (NORMALLY CONNECTED TO AUDIO AMPLIFIER AND SPEAKERS).

FIG 8

RADIO FREQUENCY BROADCASTING SYSTEMS AND METHODS USING TWO LOW-COST GEOSYNCHRONOUS SATELLITES

This application is a continuation-in-part of pending prior application Ser. No. 07/866,910 filed Apr. 10, 1992 for "RATIO FREQUENCY BROADCASTING SYSTEMS AND METHODS USING TWO LOW-COST GEOSYNCHRONOUS SATELLITES" by Robert D. Briskman Now U.S. Pat. No. 5,278,863.

BACKGROUND OF THE INVENTION

Over the past several years, proposals have been made in the United States at the Federal Communications Commission (FCC) and, internationally, at the International Telecommunications Union (ITU) to broadcast radio programs from geosynchronous satellites to receivers in mobile platforms (e.g., automobiles) and in other transportable and fixed environments. Since geosynchronous satellites are located in near-equatorial orbits approximately 42,300 kilometers from the earth's surface, such satellites appear stationary to an observer on the ground. The satellite views roughly one-third of the earth's surface below it, which allows radio broadcast coverage of such a large area or, by using directional antennas on the satellite, a sub-area such as a particular country. This potential national coverage area of many tens of millions of square kilometers for providing radio service throughout the continental United States (or other country/region) is the main feature of satellite radio broadcasting, since normal terrestrial AM/FM radio stations typically cover a much smaller area.

Radio broadcasting from satellites involves use of special receivers in mobile or fixed platforms because of technical implementation and frequency allocation/interference requirements. Consequently, proposals for building such systems have generally used UHF frequencies in the range of about 300 to about 3,000 MHz. FIG. 1 shows a typical satellite radio broadcasting system. Additional satellites can be used with the satellite system shown in FIG. 1 for providing redundancy, additional channels or both. FIG. 1 shows the most important transmission path, the path from the satellite to the mobile or fixed platforms. Since a mobile platform requires an antenna which can receive satellite signals from all azimuths and most elevation angles, the mobile platform antenna gain must be low (e.g. 2-4 dBi gain is typical). For this reason, the satellite must radiate large amounts of radio frequency transmitter power so that the mobile platform receiver can receive an adequate signal level.

In addition to the need for a high power transmitter in the satellite is the need for extra transmitter power, called "transmission margin", to overcome multipath fading and attenuation from foliage. Multipath fading occurs where a signal from a satellite is received over two or more paths by a mobile platform receiver. One path is the direct line-of-sight or desired path. On other paths, the signal from the satellite is first reflected from the ground, buildings, or trucks, and then received by a mobile platform receiver, as FIG. 2 shows. These other paths are interfering in amounts that depend on factors such as losses incurred during reflection. Among the methods for reducing multipath fading in radio systems, are the following:

1. Providing a second path for a desired signal between a transmitter and a receiver that is physically different from the first path for the signal. This is called space diversity, and is effective where only one of the two paths is strongly affected by multipath fading at any instant;

2. Providing a second transmission frequency for a desired signal between a transmitter and a receiver. This is called frequency diversity, and is effective where only one of the two frequencies is strongly affected by multipath fading at any instant; and

3. Providing signal modulation resistant to multipath fading such as spread spectrum. This method is effective where some resistance results from the large modulated frequency bandwidth used, and some resistance results from the receiver's rejection of an undesired signal's spreading code.

The transmission margin necessary to overcome multipath fading or attenuation from foliage has been both measured and estimated by experts to be in the range of about 9 to about 12 dB for satellite radio broadcast systems operating at UHF frequencies. Fortunately, multipath and attenuation from foliage seldom occur simultaneously. However, the need for 9-12 dB transmission margin means that satellite transmitter power must be increased by a factor of 8 to 12 over its initially high level. Radio broadcasting satellites operating at such power levels would be extremely large, complex and costly. To date, no commercial system of this kind is in use because of this high cost.

The systems and methods of this invention overcome these problems, by sending the same radio broadcast signals substantially simultaneously through two or more geosynchronous satellite sources separated by a sufficient number of degrees of orbital arc to minimize the effects of multipath fading and foliage attenuation, as FIG. 3 shows.

A receiver on a mobile or fixed platform receives the two signals through two physically distinct paths in space diversity methods, and selects the stronger signal, or combines the two signals. The signals can be at the same radio frequency using a modulation resistant to multipath interference, or at a different radio frequency, with or without a modulation resistant to multipath. Foliage attenuation is minimized because trees and other foliage are seldom in the line-of-sight to both satellites at the same time.

Receivers on mobile and fixed platforms receive the two signals through the two physically distinct transmission paths and select the stronger signal or combine the two signals to same radio frequency and avoid interfering with each other by use of spread spectrum modulation with code division multiple access, or by transmitting the radio signals from each satellite with opposite polarizations (e.g. cross or orthogonal polarizations such as horizontal linear/vertical linear or left circular/right circular). Where isolation of the two signals is achieved by opposite polarizations, any analog or digital signal modulation may be used. Alternatively, the two signals can be transmitted from the two satellites at different radio frequencies, which has the advantage of achieving frequency diversity capability in addition to the space diversity capability. Where different satellite frequencies are used, the signals may be transmitted using any analog or digital modulation.

In preferred embodiments, these systems and methods provide radio broadcasts from geosynchronous satellites with one-eighth or less the power needed with a single satellite. Since satellite cost is directly proportional to satellite transmitting power, the radio broadcast satellite system of this invention uses satellites about one-eighth or less as costly and as heavy as single satellite systems. The reduced satellite mass also permits the use of a lower capability, lower cost launch vehicle. Even if two launch vehicles are needed, the satellite portions of the subject system are still only about 25% as costly as a single satellite transmission system.

The subject system substantially improves reception quality by eliminating many blockage outages. Blockage outages occur when physical objects such as buildings or hills lie in the line-of-sight between the satellite and the receiver. As FIG. 4 shows, such blockage seldom occurs simultaneously on both satellite paths. FIG. 4 also shows that signal attenuation from foliage is minimized, because such attenuation results from partial signal blockage.

SUMMARY OF THE INVENTION

This invention relates to a system of two or more satellites moving in spatially separated positions on substantially the same geosynchronous orbit, each sending or relaying, substantially simultaneously, preferably at UHF frequencies in the range of about 300 to about 3,000 MHz, the same radio broadcast signal to receivers at or near the earth's surface. The spatial separation of the satellites is sufficient to minimize multipath fading, foliage attenuation, or both. Preferably, the separation between any two satellites is in the range of about 25° to about 50°. These signals are preferably digitally modulated for high fidelity, but may also be analog.

BRIEF DESCRIPTION OF THE DRAWINGS

The systems and methods of this invention can better be understood by reference to the drawings, in which:

FIG. 1 shows a UHF radio broadcast satellite system utilizing a single satellite source;

FIG. 2 shows multipath fading that occurs in UHF radio broadcasting from satellites;

FIG. 3 shows an embodiment of the UHF radio frequency broadcasting system of this invention utilizing two spatially separated satellite sources on substantially the same geosynchronous orbit;

FIG. 4 illustrates the reductions in total and partial blockage outages attainable with the two-satellite system embodiment shown in FIG. 3;

FIG. 5 shows a single correlator-type co-frequency satellite radio broadcast receiver for use with the two-satellite system embodiment shown in FIGS. 3 and 4;

FIG. 6 shows a dual correlator-type co-frequency satellite radio broadcast receiver for use with the two-satellite system embodiment shown in FIGS. 3 and 4;

FIG. 7 shows a dual-frequency satellite radio broadcast receiver for use with the two-satellite broadcast system embodiment shown in FIGS. 3 and 4; and

FIG. 8 shows a co-frequency satellite radio broadcast receiver employing two orthogonal transmission polarizations for use with the two-satellite embodiment shown in FIGS. 3 and 4.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

In the co-frequency embodiments of FIGS. 5 and 6, two satellites in substantially the same geosynchronous orbit send or relay substantially the same signal at substantially the same radio frequency. As a result, the receiver for the radio signals preferably resists multipath interference and prevents mutual self-interference that would result in signal jamming. Methods such as spread spectrum modulation (e.g., direct sequence or frequency hopping) are preferably used to achieve Code Division Multiple Access (CDMA).

A preferred receiver for use in a mobile platform such as a vehicle is a standard, one-channel direct sequence spread spectrum detection device. This device is adapted to acquire the code of the signal from any of the satellites in the system. Preferably, this code is the same for the signals from both satellites, which is accomplished by having the satellites receive the radio signal to be transmitted to the mobile platform receiver from an up-link station on the earth's surface. Such an up-link station could delay one of the two codes in time to permit faster acquisition. In the mobile receiver, when the signal level drops a fixed, predetermined amount below a threshold value, such as an amount greater than 2 dB, a code loop s opened, and re-acquisition is performed on any signal stronger than the threshold value as FIG. 5 shows in block diagram form.

In FIG. 5, the antenna receives the radio frequency signals from each of the two satellites. The signals are amplified by the radio frequency amplifier. The signals are changed from radio frequency to an intermediate frequency (IF) by the down converter. The specific intermediate frequency is chosen by the frequency of the local oscillator. One of the two signals is acquired and detected by the spread spectrum demodulator on a random basis and the other signal ignored. The signal level of the detected signal is sent to the Signal Level Memory and Threshold Comparator. The detected signal is then sent to an audio amplifier and loudspeakers for listening. The Signal Level Memory continuously receives the signal level of the detected signal and compares it with the previously sent values of signal level. When the current value of signal level falls a certain amount (i.e., to a preset threshold), the spread spectrum demodulator is forced to re-acquire a signal and attempts to do so until a signal is re-acquired whose level is greater than the threshold level.

Alternatively, the receiver in the mobile platform can have common antenna, radio and intermediate frequency (IF) equipment. The IF feeds two correlators each namely an independent spread spectrum code acquisition circuit and a detection circuit, as shown in FIG. 6.

In FIG. 6, the antenna receives the radio frequency signal from each of the two satellites. The signals are amplified by the radio frequency amplifier. The signals are changed from radio frequency to an intermediate frequency (IF) by the down converter. The specific intermediate frequency is chosen by the frequency of the local oscillator. The down converter output is split in half by the splitter, and presented to each spread spectrum demodulator. Each spread spectrum demodulator acquires and detects one of the two signals. The two signals can be recognized by either using a different code sequence for each signal, or by having an a priori time offset between the two signals' identical code sequence. Each spread spectrum demodulator sends the detected signal to either the Amplitude Sensor Switch which outputs the stronger (higher level) one to an audio amplifier and loudspeakers for listening, or to the Phase Corrector and Adder, which shifts the signals so they are in phase with each other and then sums them. The sum is outputted to an audio amplifier and loudspeakers for listening. Alternatively, the phase correc-

[illegible]n can be accomplished in the Spread Spectrum Demodulators. The codes of the signals from the satellites can be substantially identical, but offset in time or orthogonal to one another, as are Gold codes. Each of the detected signals is derived from the correlators. The signals can then be selected individually, or combined with one another to produce a single, summed output signal.

The receiver preferably outputs a signal by one of two methods. The simpler method compares the amplitudes of the signals from the two satellite sources; and chooses the stronger signal for output. Alternatively, the phases of the two signals are adjusted until they are identical to one another. The two signals are then summed to produce an output signal. This method avoids switching the receiver from one signal to another, and provides better quality signals when the transmission paths of the two signals are unaffected, or are only partially attenuated by multipath fading or foliage. The previously mentioned phase adjustments are necessary because, although both satellite sources send substantially the same signal at substantially the same time, these signals reach the mobile platform receiver with different phases since the platforms are generally at a different distance from each satellite.

In the dual-frequency embodiments, both satellites send or relay substantially the same broadcast signal, but at two substantially different frequencies. These embodiments achieve less multipath fading because both space and frequency diversity are attained simultaneously. These embodiments further permit the use of multipath resistant modulation. However, the receiver is more complex. As FIG. 7 shows, such a receiver includes two down converters, intermediate frequency amplifiers and demodulator circuits. In FIG. 7, the antenna receives the radio frequency signal from each of the two satellites. The signals are amplified by the radio frequency amplifier. The radio frequency amplifier output is split in half by the Splitter and presented to each down converter. The signals are changed from radio frequency to an intermediate frequency (IF) by the down converters. The local oscillators are set to the proper frequencies so that the signal frequencies F_1 and F_2 are converted to the same IF. The IF from the down converters feeds the demodulators. The demodulators remove the signal modulation, and send the detected signals to either the Amplitude Sensor Switch, which outputs the stronger (higher level) one to an audio amplifier and loudspeakers for listening, or to the Phase Corrector and Adder, which shifts the signals so they are in phase with each other and then sums them. The sum is outputted to an audio amplifier and loudspeakers for listening. Alternatively, the phase correction can be accomplished in the demodulators.

Dual-frequency embodiments can be as shown in FIG. 7, or can be of a type which switches rapidly between the frequencies of the two signals, or can utilize digital signal processing. The output signals from the receiver can be selected by comparing the amplitudes of the two input signals, and using the stronger signal, or the input signals can be adjusted to the same phase and summed to produce an output signal.

Alternatively, the receiver in the mobile platform can have an antenna which accepts two orthogonal (or cross) polarized radio frequency transmissions (or two antennas, each accepting one of the two polarizations), radio frequency amplification, down conversion, intermediate frequency (IF) and demodulation equipment, and equipment for either selecting the stronger signal or phasing the two signals and then combining them as shown in FIG. 8.

In FIG. 8, one or more antennas receive the same radio frequency transmission from each of the two satellites at orthogonal polarizations. One satellite sends its radio frequency transmission at one polarization (e.g., right hand circular or vertical), and the second satellite sends the same radio frequency transmission at the orthogonal polarization (e.g., left hand circular or horizontal). The signals are electrically separated from each other by the cross polarization amplified by radio frequency amplifiers, and then converted from radio frequency to intermediate frequency (IF), as by the down converters. The specific intermediate frequency is chosen by the frequency of the local oscillator.

The embodiment in FIG. 8 assumes that both satellites transmit their signals at the same radio frequency. However, different radio frequencies could be used by adding a second local oscillator. The down converters feed demodulators which are chosen to match the modulation used, since any type of analog or digital modulation can be employed. The demodulators remove the signal modulation, and send the detected signals to the amplitude sensor switch, which outputs the stronger, or higher level signal to an audio amplifier for listening, or to the phase corrector and adder, which shifts the signals so they are in phase with each other and then sums them. The summed signal is outputted to an audio amplifier and loudspeakers for listening. Alternatively, phase correction can be done in the demodulators.

What is claimed is:

1. A method for reducing satellite-based transmitter power in a radio broadcasting system adapted to broadcast radio signals having frequencies in the range of about 300 MHz to about 3,000 MHz comprising:

broadcasting on a first path a first broadcast signal that includes audio program information from a first satellite source traveling on a substantially geosynchronous orbit;

substantially simultaneously broadcasting on a second path a second broadcast signal having substantially the same content and frequency as said first broadcast signal from a second satellite source on said substantially geosynchronous orbit, said second satellite source and said second path being spaced from said first satellite source and said first path a predetermined number of degrees to reduce the power needed to transmit said first and said second signals to a receiver at or near the earth's surface; and

assembling and producing said broadcast signal as an output signal from said first broadcast signal and said second broadcast signal at a plurality of fixed receivers having at least one channel to receive said first broadcast signal and at least one channel to receive said second broadcast signal and a plurality of mobile receivers having at least one channel to receive said first broadcast signal and at least one channel to receive said second broadcast signal located at or near the earth's surface.

2. A method for reducing satellite-based transmitter power in a radio broadcasting system adapted to broadcast radio signals having frequencies in the range of about 300 MHz to about 3,000 MHz comprising:

broadcasting on a first path a first broadcast signal that includes audio program information from a first satellite source traveling on a substantially geosynchronous orbit;

substantially simultaneously broadcasting on a second path a second broadcast signal with substantially identical content from a second satellite source on said substantially geosynchronous orbit, said second satellite source and said second path being spaced from said first satellite source and said first path a predetermined number of degrees to reduce the power needed to transit said first and said second broadcast signal to the earth's surface, said second broadcast signal having a frequency different from the frequency of said first broadcast signal; and

assembling and producing said broadcast signal as an output signal from said first and said second broadcast signals at a plurality of fixed receivers having at least one channel to receive said first broadcast signal and at least one channel to receive said second broadcast signal and a plurality of mobile receivers having at least one channel to receive said first broadcast signal and at least one channel to receive said second broadcast signal located at or near the surface of the earth.

3. A method for improving signal reception in a radio system comprising:

broadcasting on a first path of first broadcast signal that includes audio program information having a frequency in the range of about 300 MHz to about 3,000 MHz from a first satellite source traveling on a substantially geosynchronous orbit;

substantially simultaneously broadcasting on a second path a second broadcast signal with identical content having substantially the same frequency as said first broadcast signal or having a frequency different from the frequency of said first broadcast signal from a second satellite source on said substantially geosynchronous orbit, said second satellite source and said second path being spaced from said first satellite source and said first path a predetermined number of degrees to improve reception of said first and said second broadcast signals at a plurality of fixed receiver and a plurality of mobile receivers located at or near the earth's surface; and

assembling and producing said broadcast signal as an output signal from said first broadcast signal and said second broadcast signal at said plurality of fixed receivers having at least one channel to receive said first broadcast signal and at least one channel to receive said second broadcast signal and said plurality of mobile receivers having at least one channel to receive said first broadcast signal and at least one channel to receive said second broadcast signal.

4. A method for reducing foliage attenuation and signal outage from radio path blockage in a radio broadcasting system adapted to broadcast signals having frequencies in the range of about 300 MHz to about 3,000 MHZ comprising:

broadcasting on a first path a first broadcast signal that includes audio program information having a frequency in said range from a first satellite source traveling on a substantially geosynchronous orbit;

substantially simultaneously broadcasting on a second path a second broadcast signal with identical content having substantially the same frequency as said first broadcast signal or having a frequency different from the frequency of said first broadcast signal from a second satellite source on said geosynchronous orbit, said second satellite source and said second path being spaced from said first satellite source and said first path a predetermined number of degrees to minimize foliage attenuation or radio path blockage; and

assembling and producing said broadcast signal as an output signal from said first broadcast signal and said second broadcast signal at a plurality of fixed receivers having at least one channel to receive said first broadcast signal and at least one channel to receive said second broadcast signal and a plurality of mobile receivers having at least one channel to receive said first broadcast signal and at least one channel to receive said second broadcast signal located at or near the surface of the earth.

5. A UHF radio system adapted to broadcast signals having frequencies in a range of about 300 MHz to about 3,000 MHz comprising:

a broadcasting source for broadcasting on a first path a first broadcast signal that includes audio program information on a first satellite source traveling in a substantially geosynchronous orbit;

a broadcasting source for broadcasting on a second path a second broadcast signal from a second satellite source traveling in said substantially geosynchronous orbit, said second satellite source and said second path being spaced from said first satellite source and said first path a predetermined number of degrees to minimize outage and fading of said first and said second broadcast signals; and

a plurality of fixed receivers and a plurality of mobile receivers for receiving said first and said second broadcast signals, each of said fixed and said mobile receivers being located at or near the surface of the earth, each of said receivers being adapted to produce said broadcast signal as an output signal from said first and said second broadcast signals, each of said receivers including at least one channel to receive said first broadcast signal and at least one channel to receive said second broadcast signal.

6. The system of claim 1 or claim 2 further comprising a UHF radio receiver that comprises means for measuring the signal strengths of said first and said second signals, and means for forming and outputting an output signal from said first and said second signals.

7. The system claim 3 wherein said first satellite source comprises at least two separate satellites.

8. The system claim 3 or claim 5 wherein said second satellite source comprises at least two separate satellites.

9. The method of claim 1 or claim 2 or claim 3 or claim 4 wherein said predetermined number of degrees is in the range of about 25 degrees to about 50 degrees

10. The method of claim 1 or claim 2 or claim 3 further comprising broadcasting said first signal and said second signal at polarizations where the frequency of said first signal is substantially the same as the frequency of said second signal.

11. The system of claim 1 or claim 2 or claim 3 wherein said broadcasting means are adapted to broadcast said first signal and said second signal at opposite polarizations where the frequency of said first signal is substantially the same as the frequency of said second signal.

12. The method of claim 1 or claim 2 or claim 3 or claim 4 wherein said first satellite source comprises at least two separate satellites to provide additional broadcast signal paths.

13. The method of claim 1 or claim 2 or claim 3 or claim 4 wherein said second satellite source comprises at least two separate satellites to provide additional broadcast signal paths.

14. The method of claim 1, or claim 2 or claim 3 or claim 4 wherein said predetermined number of degrees is in the range of about 25 degrees to about 50 degrees.

15. The method of claim 1 or claim 2 or claim 3 or claim 11 further comprising broadcasting said first broadcast signal and said second broadcast signal at opposite polarizations, and where the frequency of said first broadcast signal is substantially the same as the frequency of said second broadcast signal.

16. The method of claim 1 or claim 2 or claim 3 or claim 11 wherein said first broadcast signal and said second broadcast signal are at opposite polarization and where the frequency of said first signal is different from the frequency of said second broadcast signal.

17. The system of claim 5 further comprising, in each of said receivers, means for measuring the strengths of broadcast signals from said first and second satellite sources, and means for selecting the stronger broadcast signal from said first and said second signals for output.

18. The system of claim 5 wherein said receiver includes means for combining said first and said second broadcast signals.

19. The system of claim 5 or claim 17 or claim 18 further comprising means for modulating said first and said second broadcast signals to reduce multipath fading.

20. The system of claim 5 or claim 17 or claim 18 or claim 19 wherein said second satellite source is adapted to produce a second broadcast signal having a frequency different from the frequency of said first broadcast signal.

21. The system of claim 5 or claim 17 or claim 18 or claim 19 further comprising a UHF radio receiver that comprises means for measuring the signal strengths of said first and said second broadcast signals and means for forming and outputting the broadcast source from said first and said second broadcast signals.

22. The system of claim 5 or claim 17 or claim 18 or claim 19 wherein said second satellite source is adapted to produce a second broadcast signal having a polarization opposite from the polarization of said first broadcast signal.

23. The method of claim 1 or claim 2 or claim 3 or claim 4 wherein said assembling step comprises selection of said first broadcast signal or said second broadcast signal for output from at least one of said receivers.

24. The method of claim 1 or claim 2 or claim 3 or claim 4 wherein said assembling step comprises combining said first broadcast signal and said second broadcast signal to produce said output signal at at least one of said receivers.

25. The method of claim 1 or claim 2 or claim 3 or claim 4 wherein said predetermined number of degrees is sufficient to position substantially all of said receivers substantially within line-of-eight of said first satellite source and said second satellite source.

26. The system of claim 5 or claim 17 or claim 18 or claim 19 wherein said first satellite source and said second satellite source are spaced apart a distance sufficient to position substantially all of said receivers substantially within line-of-sight of said first and said second satellite sources.

27. The method of claim 1 or claim 2 or claim 3 or claim 4 further comprising utilizing spread spectrum modulation in said broadcasting.

28. The system of claim 5 wherein said broadcasting source utilizes spread spectrum modulation.

* * * * *

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Has received an application for a patent for a new and useful invention. The title and description of the invention are enclosed. The requirements of law have been complied with, and it has been determined that a patent on the invention shall be granted under the law.

Therefore, this

United States Patent

Grants to the person or persons having title to this patent the right to exclude others from making, using or selling the invention throughout the United States of America for the term of seventeen years from the date of this patent, subject to the payment of maintenance fees as provided by law.

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NOTICE

If the application for this patent was filed on or after December 12, 1980, maintenance fees are due three years and six months, seven years and six months, and eleven years and six months after the date of this grant, or within a grace period of six months thereafter upon payment of a surcharge as provided by law. The amount, number, and timing of the maintenance fees required may be changed by law or regulation. Unless payment of the applicable maintenance fee is received in the Patent and Trademark Office on or before the date the fee is due or within a grace period of six months thereafter, the patent will expire as of the end of such grace period.

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United States Patent [19]

Briskman et al.

[11] Patent Number: 5,485,485

[45] Date of Patent: Jan. 16, 1996

[54] RADIO FREQUENCY BROADCASTING SYSTEMS AND METHODS USING TWO LOW-COST GEOSYNCHRONOUS SATELLITES AND HEMISPHERICAL COVERAGE ANTENNAS

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[21] Appl. No.: **227,045**

[22] Filed: **Apr. 13, 1994**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 48,663, Apr. 16, 1993, Pat. No. 5,319,673, which is a continuation-in-part of Ser. No. 866,910, Apr. 10, 1992, Pat. No. 5,278,863.

[51] **Int. Cl.**[6] **H04B 1/69**

[52] **U.S. Cl.** **375/200**; 655/13.2

[58] **Field of Search** 375/200; 455/12.1, 455/13.1, 13.2

[56] **References Cited**

U.S. PATENT DOCUMENTS

5,278,863	1/1994	Briskman et al.	375/200
5,319,673	6/1994	Briskman et al.	375/200

Primary Examiner—Salvatore Cangialosi

[57] **ABSTRACT**

The methods and systems for reducing multipath fading and outage from blockage in a radio broadcasting system that is adapted to simultaneously broadcast signals having frequencies in the range of about 300 MHz to about 3,000 MHz from two or more satellite sources traveling on a substantially geosynchronous orbit with the satellite sources separated from one another by a sufficient distance to minimize outage from physical blockages and multipath fading of signals from these satellites and received by a plurality of fixed and mobile platforms using substantially flat, hemispherical coverage antennas, each antenna having an outer diameter no greater than about 10 inches and each adapted to receive frequencies in the range of about 300 MHz to about 3,000 MHz.

29 Claims, 9 Drawing Sheets